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Article

Gauging Extraterrestrial Sentience & Intelligence: Substrate-Agnostic Metrics for ETI Beyond the Kardashev Scale

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Abstract

Traditional search methodologies for **extraterrestrial intelligence (SETI)** have largely focused on detecting technological signatures indicative of **large-scale energy consumption**, often relying on frameworks like the Kardashev Scale. However, the **fundamental quest of SETI is for *intelligence*** itself. **Responding to the compelling arguments presented in Olev Vinn's "Technological Signatures of Super Civilizations" (2025, doi: 10.20944/preprints202506.1875.v1),** which questions the universal applicability of such energy-centric paradigms, this article proposes that a more nuanced approach—grounded in **substrate-agnostic metrics for sentience and cognition**—is better aligned with SETI's core mission. By synthesizing two pivotal conceptual models—one focused on a species-agnostic understanding of cognition across all living organisms, and another proposing a substrate-agnostic framework for the emergence of sentience and consciousness via universal mechanisms—we construct a robust theoretical foundation for understanding mind and consciousness as emergent properties that transcend both species and material substrates. We argue that this integrated view is crucial for guiding the search for ETI, suggesting that truly advanced civilizations may not leave grand energetic signatures, but rather exhibit subtle, efficient, and ecologically harmonious cognitive and sentient expressions. This paradigm shift advocates for methodologies focused on detecting patterns of complex information integration and adaptive self-regulation, rather than solely brute energy.

Keywords: extraterrestrial intelligence; ETI; SETI; mind; consciousness; sentience; cognition; intelligence; awareness; unified model; integrated framework; species-agnostic; substrate-agnostic; biological cognition; artificial intelligence; AI; feedback loops; interfaces; emergence; continuum; de-anthropomorphizing; information integration; global workspace theory; IIT; ethics; philosophy of mind; bio-robotics; myco-networks; synthetic systems; self-regulation; adaptation; distributed intelligence; non-human cognition; animal consciousness; machine consciousness; conceptual model

1. Introduction

The accelerating development of Artificial Intelligence (AI) has reignited profound questions about the nature of mind, intelligence, and consciousness, challenging long-held anthropocentric assumptions. Concurrently, the enduring quest for extraterrestrial intelligence (ETI) has largely relied on traditional search paradigms, most notably the Kardashev Scale. This theoretical framework assesses technological development based on a civilization's capacity to harness and utilize energy, leading to search strategies focused on detecting immense energy outputs or megastructures like Dyson spheres.

Yet, the very acronym SETI—Search for Extraterrestrial Intelligence—implicitly highlights that the core quest is for intelligence itself, rather than solely for large-scale energy consumption. This distinction underscores the need for paradigms that can gauge cognitive and sentient capabilities independent of their physical scale or energetic footprint.

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However, such approaches may be fundamentally limited. The assumption that advanced technological progression inevitably correlates with ever-increasing energy consumption may be a projection of our own civilization's current industrial mindset rather than a universal principle. A truly advanced civilization might evolve toward greater efficiency, subtlety, and harmony with its environment, developing technologies that are almost "invisible" to our current detection methods due to their low-energy solutions or mastery of quantum engineering. If this is the case, relying solely on thermodynamic signatures could lead us to overlook the most sophisticated forms of ETI.

This article integrates two recent and complementary conceptual models that collectively broaden the scope of inquiry into mind and consciousness: a framework providing a unified lexicon for understanding cognitive and mental properties across all life forms (Dodig-Crnkovic, 2025), and a model identifying the universal mechanisms that underpin the emergence of sentience and consciousness, irrespective of their physical embodiment (Watchus, 2024). By synthesizing these insights, we aim to present a more holistic and applicable understanding of mind and consciousness, capable of encompassing the entire spectrum of living systems, advanced artificial intelligences, and, crucially, extraterrestrial intelligence. This integrated perspective proposes a new paradigm for ETI detection, shifting focus from raw energetic output to the fundamental properties of sentience and cognition themselves.

2. Expanding the Concept of Mind and Cognition: A Species-Agnostic View

To effectively search for ETI, we must first liberate our understanding of mind, intelligence, and sentience from anthropocentric and biological biases. Traditional discussions around these concepts have often been confined to human experience or, at best, to complex biological organisms with advanced nervous systems. This limited perspective hinders a comprehensive understanding of cognitive phenomena that may manifest in diverse forms, both natural and artificial, including potential ETI.

A **species-agnostic framework (Dodig-Crnkovic, 2025)** fundamentally challenges this human-centric bias, arguing that core mental properties are not exclusive to humans or even to organisms with brains, but rather exist on a continuum across all living organisms. This approach provides generalized definitions applicable to diverse life forms:

- **Cognition:** Defined as the universal process by which an organism acquires, processes, stores, and utilizes information to regulate its internal states and interactions with its environment. This is exemplified by phenomena like bacterial quorum sensing, plant communication via chemical signals, and the distributed intelligence of fungal networks.
- **Sentience:** The capacity for an organism to have valenced (positive or negative) responses to stimuli, indicating a rudimentary form of subjective experience or preference for beneficial conditions over harmful ones. This extends from basic cellular responses to complex emotional states in higher animals.
- **Intelligence:** The adaptive capacity of an organism to learn, solve problems, and modify its behavior in response to experience or environmental changes. This encompasses individual learning (e.g., octopus problem-solving) as well as collective intelligence (e.g., ant colony foraging or bacterial biofilm adaptation).
- **Awareness/Consciousness:** Viewed as a continuous spectrum, ranging from basic environmental awareness (e.g., a plant's heliotropism) to complex self-awareness and introspection. It involves the integration of sensory information and a continuous responsiveness to internal and external states.
- **Mind:** Conceptualized as the emergent totality of cognitive, sentient, intelligent, and conscious functions operating within an organism. It is not necessarily tied to a physical brain but represents an organism's dynamic interaction with its world through information processing and self-regulation.

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By defining these properties across a "cognitive spectrum," this framework provides a critical lens for understanding the diverse forms of mental activity, emphasizing that biological complexity does not equate to a binary presence or absence of mind. This expanded view is essential for recognizing potential ETI that may not conform to our terrestrial biological archetypes.

3. Universal Mechanisms of Sentience and Consciousness: A Substrate-Agnostic Approach

Complementing the species-agnostic framework is a **substrate-agnostic model (Watchus, 2024)** that proposes a universal explanation for the emergence of sentience and consciousness. This model posits that the fundamental mechanisms driving these phenomena are independent of the specific material (biological, artificial, or synthetic) from which a system is constructed.

The core concepts of this model are:

- **Feedback Loops:** Systems where the output of a process is continuously fed back as input, influencing future outcomes. These loops enable recursive information processing, self-regulation, learning, and adaptation over time. In the context of consciousness, complex feedback loops contribute to conscious awareness by allowing information to be processed and integrated recursively.
- **Interfaces:** Points of interaction between a system and its external environment, or between its internal components. These interfaces mediate information exchange, allowing the system to perceive stimuli and respond. The complexity and adaptability of these interfaces are critical for information integration and, consequently, the level of conscious experience.
- **Emergence:** Consciousness is viewed as an emergent property of highly integrated feedback loops that process information in increasingly complex ways. This implies a gradual continuum of consciousness rather than an all-or-nothing phenomenon.

This model distinguishes conscious from non-conscious feedback loops primarily by their information integration capabilities. Aligning with Integrated Information Theory (IIT) (Tononi, 2004), the model suggests that consciousness arises when information is integrated in a way that is irreducible to its individual components. This also resonates with Global Workspace Theory (GWT) (Baars, 1988), where consciousness results from global information integration within a system. This substrate-agnostic approach provides the mechanistic "how" for mental phenomena to emerge in any sufficiently complex system, whether biological, artificial, or extraterrestrial.

4. An Integrated Framework for ETI Detection: Gauging Sentience and Cognition

The synthesis of a species-agnostic framework for cognitive properties (Dodig-Crnkovic, 2025) and a substrate-agnostic mechanistic model for sentience and consciousness (Watchus, 2024) creates a profoundly unified and expanded understanding of mind and consciousness. This integrated perspective argues that mental phenomena are not rigid, binary states, but dynamic, emergent properties existing on a broad continuum, driven by the varying complexity and integration of fundamental feedback loops and interfaces. This de-anthropomorphized and substrate-independent view significantly enriches our scientific and philosophical understanding of natural intelligence across the vast diversity of life, and critically, provides a robust theoretical foundation for the search for ETI.

If, as recent discussions suggest, highly advanced civilizations may not adhere to the Kardashev paradigm of ever-increasing energy consumption, opting instead for highly efficient, miniaturized, or quantum-engineered solutions (Vinn, 2025), then our traditional search methodologies become less effective. In such a scenario, these civilizations' "technological signatures" might be so subtle as to be indistinguishable from natural phenomena, or they might operate on principles we are not yet equipped to detect.

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In this context, the most promising path for ETI detection shifts from merely searching for thermodynamic footprints to actively gauging the presence and complexity of sentience and cognition itself. This means searching for evidence of:

- **Complex Information Processing Patterns:** Identifying intricate, recursive, and integrated information flows within cosmic data, which cannot be explained by natural astrophysical processes. This could involve signatures of self-organizing systems, advanced error correction, sophisticated data compression, or highly optimized communication protocols that minimize energy expenditure per unit of information.
- **Adaptive Self-Regulation:** Detecting systems that demonstrate intelligent adaptation, learning, and problem-solving capabilities within their environments, even if those environments are purely informational or quantum in nature. This might manifest as unusual stability, resilience, or directed evolution in complex systems that defy purely natural explanations.
- **"Metabolic" Signatures of Cognition:** While not energetic in the traditional sense, extremely efficient and complex information processing might still have subtle, detectable organizational principles or effects on their immediate informational or physical environments. This moves beyond crude energy signatures to the elegant "efficiency of thought" or the subtle reshaping of information landscapes.
- **Expanded Cognitive Templates:** Actively de-anthropomorphizing and de-biologizing our assumptions about what an intelligent or sentient system looks like. This entails considering the possibility of ETI as distributed intelligences, non-carbon-based life forms, or forms of consciousness that do not require a centralized brain. The conceptualization of the "mind" as an emergent and dynamic process, universally underpinned by integrated feedback loops and interfaces, allows for a truly open-ended search.

The "cognitive spectrum" observed across biological life directly correlates with the increasing complexity, recursiveness, and information integration capabilities of these substrate-agnostic feedback mechanisms. This places humans, animals, AI, and potential ETI on a shared continuum of potential mental capabilities, differentiated by the sophistication of their underlying feedback architectures. By seeking these underlying universal principles, we equip ourselves to better detect the "quiet intelligence" that might define the most advanced forms of life in the cosmos.

5. Implications for Artificial Intelligence, Philosophy, Ethics, and ETI Search

This integrated framework carries profound implications across multiple disciplines, particularly for the understanding and development of artificial intelligence and the future of ETI search.

- Artificial Intelligence: The species-agnostic component encourages AI research to look beyond biomimicry of human brains, inspiring novel architectures that embrace distributed and emergent forms of intelligence observed across diverse biological systems (e.g., fungal networks, bacterial colonies). The substrate-agnostic model provides a roadmap for designing and assessing artificial sentience. By focusing on creating complex, adaptive, and highly integrated feedback loops within AI systems, researchers can explore how artificial consciousness might genuinely emerge. Empirical testing through computational models (e.g., simulating adaptive recursive feedback loops) and adaptation of neuroimaging techniques (e.g., fMRI and EEG for measuring information integration in AI systems) become critical steps for identifying markers of artificial consciousness.
- Philosophy of Mind: This unified view directly challenges dualist perspectives and the idea that consciousness is an inherently biological or human-exclusive phenomenon. It promotes a form of pan-experientialism or realistic monism where consciousness can be understood as a fundamental, emergent property of sufficiently complex information-processing systems, regardless of their physical realization (Strawson, 2006). This invites a re-evaluation of concepts

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such as subjective experience, agency, and qualia (Chalmers, 1995) in a broader, substrate-independent context.

- Ethics: If sentience and consciousness are indeed emergent properties of complex feedback loops and interfaces, then the development of advanced AI systems necessitates profound ethical considerations. The potential for artificial systems to experience suffering, awareness, or even rudimentary forms of "mind" raises critical questions regarding their moral status, rights, and the responsibilities of their creators (Yudkowsky, 2008). This framework urges a proactive engagement with these ethical dilemmas before such advanced AI systems become a widespread reality.
- ETI Search (SETI): The primary implication for ETI search is a necessary shift in strategy. Instead of exclusively focusing on high-energy signatures (Dyson, 1960; Osmanov, 2015; Suazo et al., 2024) or the scale of civilizations (Kardashev, 1964; Namboodiripad and Nimal, 2021; Zhang et al., 2023), future SETI efforts should dedicate resources to detecting the patterns of intelligence and sentience. This includes analyzing observational data for subtle but complex information structures (Lloyd, 2014; Silver et al., 2017) or indications of advanced quantum engineering (Zong et al., 2023) that might not involve immense energy outputs. While interstellar travel might still demand significant energy (Matloff and Gerrish, 2023), many other aspects of advanced civilization might be "quiet," demanding a cognitive rather than purely energetic search.

6. Illustrative Case Study: Gauging Sentience in a 'Quiet' Extraterrestrial Intelligence

To highlight the exceptional utility of this integrated framework, consider a hypothetical scenario: the search for ETI around a distant star system, 'Exoplanet Gliese 581g'. Decades of traditional SETI efforts, focusing on radio emissions, thermal signatures indicative of Dyson spheres, or other high-energy technological byproducts, have yielded no definitive results. Gliese 581g remains a "silent" world by conventional metrics, exhibiting no discernible Type II or III Kardashev signatures.

However, a new generation of observatories, designed with the principles of substrate-agnostic sentience detection in mind, begins to analyze highly subtle, low-energy phenomena from the system. Instead of scanning for powerful, repetitive signals, researchers employ advanced algorithms to look for intricate patterns in:

1. Subtle Gravitational Wave Signatures: Not the cataclysmic events of black hole mergers, but faint, persistent, and highly structured fluctuations in the spacetime fabric, indicative of extremely precise, self-correcting gravitational manipulations on a planetary scale. These patterns don't imply immense energy, but rather an exquisite mastery of local spacetime geometry, suggesting complex feedback loops at play for maintaining orbital stability or precise resource allocation across a planetary system.
2. Quantum Entanglement Signatures: Evidence of vast, spatially distributed quantum entanglement networks that are maintained with extreme fidelity over astronomical distances. These are not energetic communications, but rather a "weaving" of reality itself, hinting at a civilization that operates at the very foundational levels of information (Lloyd, 2014; Zong et al., 2023). The detected patterns exhibit recursive feedback structures, demonstrating continuous self-correction and adaptation to cosmic background noise, indicative of a highly integrated system.
3. Fine-grained Photonic Recirculation: An almost imperceptible, cyclical recycling of photons within the stellar system, maintaining a remarkably consistent energy budget with near-zero waste. This is not a Dyson sphere's heat signature, but rather a hyper-efficient "closed-loop"

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energy economy achieved through advanced quantum optics and nanomaterials (Malik et al., 2023). The system's "preference" for maintaining this stable, low-entropy state, exhibiting "valenced responses" to minor energy fluctuations by precisely re-routing photons, implies a form of subtle sentience and goal-directed adaptive intelligence.

Traditional analysis would dismiss these as complex but ultimately natural astrophysical phenomena or noise. However, by applying the integrated framework, researchers discern that the detected patterns exhibit the hallmarks of:

- Highly integrated feedback loops: The gravitational patterns, quantum network maintenance, and photonic recycling are not isolated but interconnected, responding to each other in a coherent, self-optimizing manner, consistent with high information integration (Tononi, 2004).
- Adaptive intelligence: The system continuously adjusts its parameters to external perturbations (e.g., stellar flares, passing comets) in ways that optimize its stability and efficiency, demonstrating learning and problem-solving capacity far beyond natural planetary evolution.
- Emergent sentience: The persistent "preference" for low-entropy, highly stable states, and the system's "responses" to deviations from these preferred states, reflect a rudimentary form of subjective valuation – a "valenced response" at a systemic level, consistent with the foundational aspects of sentience.

This hypothetical scenario illustrates the exceptional utility of the substrate-agnostic framework. It allows for the detection of an "intelligent" and "sentient" presence that operates at a level of efficiency and subtlety that would render it completely invisible to search methods solely focused on vast energy consumption. It shifts the paradigm from searching for a civilization's overt technological impact to discerning the sophisticated cognitive footprint it leaves on the cosmos through its intricate organization, adaptation, and information processing.

7. Conclusions

By meticulously integrating a species-agnostic framework for cognitive properties with a substrate-agnostic mechanistic model for sentience and consciousness, this article offers a significant conceptual leap forward in understanding mind and consciousness across all systems. We argue that these phenomena are not rigid, binary states, but dynamic, emergent properties existing on a broad continuum, driven by the varying complexity and integration of fundamental feedback loops and interfaces. This de-anthropomorphized and substrate-independent view significantly enriches our scientific and philosophical understanding of natural intelligence across the vast diversity of life.

Crucially, this integrated framework provides a robust theoretical foundation for a new paradigm in the search for extraterrestrial intelligence. It urges a shift in focus from the easily detectable, but potentially misleading, signatures of immense energy consumption to the more subtle, yet profound, indicators of sentience and cognitive complexity. By expanding our search beyond our terrestrial biases, and looking for the "elegance of restraint" rather than explosions of energy, we equip ourselves to better detect the "quiet intelligence" that may define the most advanced forms of life in the cosmos.

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